KEY
P. 1 of 3

Temperature Scales and Thermal Expansion Worksheet 1 (Linear)

1. A 1.00 x 10^4 meter steel railroad track with a coefficient of linear expansion of 12 x 10^{-6} per degree Celsius changes temperature from 18°C to 38°C. By how many meters will the railroad tracks expand?

$\Delta L = ?$
$\alpha = 12\times10^{-6}\,°C^{-1}$
$L_0 = 1.00\times10^4\,m$
$T_f = 38°C$
$T_i = 18°C$

$\Delta L = \alpha L_0 \Delta T$
$\Delta L = 12\times10^{-6}\,°C^{-1}(1.00\times10^4\,m)(38°C - 18°C)$
$\Delta L = 2.4\,m$

2. Railroad tracks are segmented into short pieces. Why is this a good idea in a place like Saskatchewan?

3. The Eiffel Tower in Paris is 324 meters tall, and is made primarily of iron, which has a coefficient of linear expansion of 12 x 10^{-6}. The average low in Paris is 1.00°C and the average high is 24°C. What is average change in height the tower experiences each year?

$L_0 = 324\,m$
$\alpha = 12\times10^{-6}\,°C^{-1}$
$T_f = 24°C$
$T_i = 1.00°C$
$\Delta L = ?$

$\Delta L = \alpha L_0 \Delta T$
$\Delta L = 12\times10^{-6}\,°C^{-1}(324\,m)(24°C - 1.00°C)$
$\Delta L \approx 0.089\,m$

4. By how much would you need to heat a 10.0 foot bar of zinc to make it expand by one inch? The coefficient of linear expansion of zinc is 30 x 10^{-6} per degree Celsius.

$\Delta T = ?$
$\alpha = 30\times10^{-6}\,°C^{-1}$
$L_0 = 10.0\,ft$
$\Delta L = 1\,in = \frac{1}{12}\,ft = 0.083\,ft$

$\Delta L = \alpha L_0 \Delta T$
$\frac{\Delta L}{\alpha L_0} = \Delta T$

$\frac{0.083\,ft}{30\times10^{-6}\,°C^{-1}(10.0\,ft)}$
$276.\bar{6} = \Delta T$

$\Delta T \approx 280°C$

5. A metal bar changes in length by 1.00 meter with a 150 degree Celsius change in temperature. It's coefficient of linear expansion is 25 x 10^{-6} per degree Celsius. What is the metal bar's original length?

$\Delta L = 1.00\,m$
$\Delta T = 150°C$
$\alpha = 25\times10^{-6}\,°C^{-1}$
$L_0 = ?$

$\Delta L = \alpha L_0 \Delta T$
$\frac{\Delta L}{\alpha \Delta T} = L_0$
$\frac{1.00\,m}{(25\times10^{-6}\,°C^{-1})(150°C)}$

$L_0 \approx 270\,m$

6. An unknown metal alloy is being tested to discover its thermal properties to see if it is suitable for use as a component in an aircraft wing. The alloy is formed into a bar measuring 1.00 meter in length, and is then heated from its starting temperature of 30 degrees Celsius to a final temperature of 100.0 degrees Celsius. The length of the heated bar is measured to be exactly 1.002 meters in length. What is the coefficient of thermal expansion of the alloy to 2 significant figures?

$L_o = 1.00m$
$T_i = 30°C$
$T_f = 100.0°C$
$L_f = 1.002m$

$\Delta L = \alpha L_o \Delta T$

$\frac{\Delta L}{L_o \Delta T} = \alpha$

$\frac{(1.002m - 1.00m)}{1.00m(100.0°C - 30°C)} = \alpha$

$\alpha \approx 2.6 \times 10^{-5}\ °C^{-1}$

7. The aircraft wing from problem 6 experiences temperature extremes that span 210 degrees Celsius. The component for the wing will have a length of 3.00 meters. Testing indicates that the aircraft wing will remain stable only if the component never expands to a length larger than 3.017 meters. If the component is made from the metal alloy in question, will it meet this requirement?

$\Delta T = 210°C$
$L_o = 3.00m$
$\alpha = 2.6 \times 10^{-5}\ °C^{-1}$
$\Delta L = ?$

$\Delta L = \alpha L_o \Delta T$

$\Delta L = 2.6 \times 10^{-5}\ °C^{-1}(3.00m)(210°C)$

$\Delta L \approx 0.016m$

$L_f = 3.00m + 0.016m \Rightarrow 3.016m < 3.017m$

Yes

8. What are 40°C and –45°C in Kelvin?

$40 + 273 =$ 313K $-45 + 273 =$ 228K

9. A rod 1.0 m long expands 0.50 mm when heated from 20.°C to 84°C. What is the coefficient of linear expansion of the material from which the rod is made?

$L_o = 1.0m$
$\Delta L = 0.50mm = 0.00050m$
$T_f = 84°C$
$T_i = 20.°C$
$\alpha = ?$

$\Delta L = \alpha L_o \Delta T$

$\frac{\Delta L}{L_o \Delta T} = \alpha$

$\frac{0.00050m}{1.0m(84°C - 20.°C)} = \alpha$

$\alpha \approx 7.8 \times 10^{-6}\ °C^{-1}$

10. A steel girder is 32.10 m at 20.°C. If the temperature drops to 5.0°C, what is the length of the girder? (Answer to 2 decimal places.)

$L_o = 32.10m$
$T_i = 20.°C$
$T_f = 5.0°C$
$L_f = ?$
$\alpha = 12 \times 10^{-6}\ °C^{-1}$

$\Delta L = \alpha L_o \Delta T$

$L_f - L_i = \alpha L_o \Delta T$

$L_f = \alpha L_o \Delta T + L_i$

$L_f = 12 \times 10^{-6}\ °C^{-1}(32.10m)(5.0°C - 20.°C) + 32.10m$

$L_f \approx 32.09\ m$

11. A metal rod has a length of 100. cm at 200.°C. At what temperature will the length be 99.6 cm if the coefficient of linear expansion of the material in the rod is $2.0 \times 10^{-5}\ °C^{-1}$?

$L_o = 100.\ cm$
$T_i = 200.°C$
$L_f = 99.6 cm$
$T_f = ?$
$\alpha = 2.0 \times 10^{-5}\ °C^{-1}$

$\Delta L = \alpha L_o \Delta T$
$\Delta L = \alpha L_o (T_f - T_i)$
$\frac{\Delta L}{\alpha L_o} = T_f - T_i$
$\frac{\Delta L}{\alpha L_o} + T_i = T_f$

$T_f = \frac{(99.6\ cm - 100.\ cm)}{(2.0 \times 10^{-5}\ °C^{-1})(100.\ cm)} + 200°C$

$T_f = 0.00\ °C$

$T_f = 0.00 \times 10^{0}\ °C$

12. What is the final length of a 6.00 m aluminum rod if the temperature changes from 410.0 K to 250.0 K?

$L_f = ?$
$L_o = 6.00 m$
$T_i = 410.0 K$
$T_f = 250.0 K$
$\alpha = 24 \times 10^{-6}\ °C^{-1}$

$\Delta L = \alpha L_o \Delta T$
$L_f - L_i = \alpha L_o \Delta T$
$L_f = \alpha L_o \Delta T + L_i$

$L_f = (24 \times 10^{-6}\ °C^{-1})(6.00 m)(250.0 K - 410.0 K) + 6.00 m$

$L_f \approx 5.98 m$

13. What is the change in the length of a 15.0 m steel rail as it is cooled from 1535°C to 20°C?

$\Delta L = ?$
$L_o = 15.0 m$
$T_i = 1535°C$
$T_f = 20°C$
$\alpha = 12 \times 10^{-6}\ °C^{-1}$

$\Delta L = \alpha L_o \Delta T$

$\Delta L = 12 \times 10^{-6}\ °C^{-1} (15.0 m)(20°C - 1535°C)$

~~$\Delta L \approx -0.273 m$~~

$\Delta L \approx -0.27 m$

14. A 200.0 cm copper wire and a 201 cm platinum ($9.0 \times 10^{-6}\ °C^{-1}$) wire are both at exactly 0°C. At what temperature will they be of equal length?

$L_c = 200.0 cm$
$L_p = 201 cm$
$T_i = 0°C$
$\therefore \Delta T = T_f - T_i = T_f$
$L_f = L_f$
$\alpha_c = 17 \times 10^{-6}\ °C^{-1}$
$\alpha_p = 9.0 \times 10^{-6}\ °C^{-1}$

$\Delta L = \alpha L_o \Delta T$
$L_f - L_i = \alpha L_o \Delta T$
$L_f = \alpha L_o \Delta T + L_i$
$L_{fc} = L_{fp}$

$\therefore \alpha_c L_c T_f + L_c = \alpha_p L_p T_f + L_p$
$\alpha_c L_c T_f - \alpha_p L_p T_f = L_p - L_c$
$T_f(\alpha_c L_c - \alpha_p L_p) = L_p - L_c$
$T_f = \frac{L_p - L_c}{\alpha_c L_c - \alpha_p L_p}$

$T_f = \frac{201 cm - 200 cm}{(17 \times 10^{-6})(200.0 cm) - (9.0 \times 10^{-6})(201 cm)}$

$T_f \approx 629°C$

15. A circular pyrex ($4.0 \times 10^{-6}\ °C^{-1}$) watch glass of 10.0 cm diameter at 21°C is heated to 501°C. What change will be found in the circumference of the glass?

$\alpha = 4.0 \times 10^{-6}\ °C^{-1}$
$L_o = 10.0 cm$
$T_i = 21°C$
$T_f = 501°C$
$\Delta L = ?$
$\Delta C = ?$

$\Delta L = \alpha L_o \Delta T$
$\Delta L = 4.0 \times 10^{-6}\ °C^{-1} (10.0 cm)(501°C - 21°C)$
$\Delta L \approx 0.0192 cm$
$C = \pi d$
$\therefore \Delta C = \pi \Delta L$

$\Delta C = \pi (0.0192 cm)$

$\Delta C \approx 0.060 cm$